OVERVIEW OF THE TEXAS LOANSTAR MONITORING PROGRAM

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ABSTRACT

The Texas LoanSTAR program is an eight year, $98 million revolving loan program, funded by oil overcharge dollars, for energy conservation retrofits in Texas state, local government and school buildings. The program began in 1988. Public sector institutions participating in the program must repay the loans according to estimated energy savings from an energy audit. This paper provides an overview of the monitoring program at Texas A&M University, the prime subcontractor to the Texas Governor's Energy Management Center on the LoanSTAR Program.

As part of this program, a statewide energy Monitoring and Analysis Program (MAP) has been established. The major objectives of the LoanSTAR MAP are to: 1) verify energy and dollar savings of the retrofits, 2) reduce energy costs by identifying operational and maintenance improvements, 3) improve retrofit selection in future rounds of the LoanSTAR program, and 4) initiate a data base of energy use in institutional and commercial buildings in Texas.

Currently, the program is monitoring hourly data from over two dozen buildings using public domain polling procedures that collect information from microcomputer-based field recorders supplied by several manufacturers. Future efforts will include investigating the feasibility of reducing energy monitoring costs by utilizing Energy Management and Control Systems (EMCS)-based monitoring and expand the program into additional sites.

1. INTRODUCTION

1.1. Background

In 1988, the Governor's Energy Management Center (GEMC) of Texas received approval from the U.S. Department of Energy to establish a $98.6 million statewide retrofit demonstration revolving loan program, the LoanSTAR (Loan to Save Taxes and Resources) program. The LoanSTAR program uses a revolving loan financing mechanism to fund energy-conserving retrofits in state, public school and local government buildings. Retrofit projects are identified by energy audits conducted by engineering teams under contract to the GEMC. Each retrofit competes for funds on the basis of the estimated payback period, ability to repay the loan through energy savings, engineering assessment of the viability of the retrofit, and the feasibility of metering the project effectively.

1.2. Program Overview

The LoanSTAR program is being implemented in two phases. Phase I targets state agencies and institutions that received energy audits in 1984-86. Capital intensive energy-conserving improvements totaling $40 million are candidates for funding in this phase. Public schools and local governments are targeted for Phase II of the LoanSTAR program. Previous engineering audits of these facilities conducted under the Institutional Conservation Program (ICP) revealed potential energy savings similar to those in state buildings.

The projects funded by LoanSTAR primarily include retrofits to lighting, HVAC systems, building shell, electric motors, energy management and control systems, boilers, and thermal energy recovery systems. Retrofits using alternative or renewable energy systems and load management also are considered.

Loans are made by the GEMC to the public entity, i.e., state agency, public school district, local government based on the audit recommendations. The length of the loan can be up to four years. Repayments are made semi-annually at an annual interest rate of 4.04 percent. Loan proceeds are used to pay for the retrofits, engineering and design, and installation expenses. The cost of the on-site metering and energy analysis is paid from the interest-income derived from the program. A breakdown of the program costs by task is given in Table 1. Total metering costs must not exceed three percent of all retrofit costs.

1.3. Objectives of the Monitoring and Analysis Program

The LoanSTAR Monitoring and Analysis Program (MAP) was designed to serve the differing needs of the many participants in the LoanSTAR revolving loan program. The energy monitoring program's first objective is to determine whether retrofits save as much as estimated in audits. When necessary, a monitoring plan is developed for each retrofitted facility to verify savings. Verification of savings includes measurement of consumption data before and after the retrofit, and analysis of the data to account for weather, changes in operation of the building, and so on. This is a quality assurance measure to insure that agencies purchasing retrofits receive real savings from the LoanSTAR retrofits.

The second objective of the MAP is to reduce energy costs of a building by evaluating its energy-using characteristics. Previous experience at several universities and at a large federal office building in Washington, D.C., has demonstrated that continuous energy monitoring and

Table 1: Budget Breakdown for First Year Monitoring Program

Task	(Man-months)	Personnel ($)	Travel, Supplies, Etc. ($)	Total ($)
1	29	$103,000	$2,500	$105,500
2	37	$103,000	$4,500	$107,500
3	14	$44,000	$30,000	$74,000
4	21	$59,000	$21,000	$80,000
5	65	$166,000	$105,000	$271,000
TOTAL	166	$475,000	$163,000	$638,000

NOTE:

(1) Additional first year costs to establish the MARC were $110,000.
(2) Includes $81,000 for computer hardware and software, plus a 50% in-kind computer hardware, and software contribution by Texas A&M.
(3) Estimated hardware to monitor $26 million in retrofits is $780,000.

analysis can lead to changes in operation and maintenance that can substantially reduce energy use in a building [1, 2, 3].

Some retrofits may prove more effective and others less effective than expected. This knowledge enables engineers who perform future audits to make more cost-effective recommendations. Hence, the third objective is to increase the cost-effectiveness of future rounds of the LoanSTAR program by screening out ineffective retrofits.

The final major objective of energy monitoring is the establishment of an end-use data base for institutional and commercial buildings in Texas. The number and types of buildings in LoanSTAR for which detailed data will be available will be limited, so data should be considered a supplement to existing data bases, such as ELCAP, BECA, and EIA. It will include data to evaluate retrofit effectiveness in a large number of buildings in hot and humid climates. These data can be used by utility planners, building research scientists, and government policy makers. A more detailed description of the energy monitoring and analysis program is available in the report by [4].

2. THE MONITORING AND ANALYSIS PROGRAM

2.1. Organization

The LoanSTAR MAP is administered through the Governor's Energy Management Center (GEMC) and conducted primarily at the Energy Systems Laboratory at Texas A&M University. A Monitoring and Analysis Review Committee (MARC) has been established to provide ongoing contact with other energy monitoring and analysis efforts to ensure incorporation of applicable techniques and results from those efforts. Organizations with participants on the MARC include the U.S. Department of Energy (DOE), the Electric Power Research Institute (EPRI), Lawrence Berkeley Labs (LBL), Oak Ridge National Labs (ORNL), Princeton, Massachusetts Institute of Technology (MIT), the University of Texas, Houston Lighting and Power (HL&P), as well as the GEMC.

The primary work for the MAP has been divided into five tasks (Figure 1), which include audit review and assignments, hardware and vendor selection, a calibration facility, systems communications bench test, and energy monitoring analysis and reporting. Each of the five primary tasks utilizes subcontractors as needed to complete the work in a timely fashion.

2.2. Task 1: Audit Review and Assignment

The GEMC has contracted with eight engineering consulting firms to conduct audits for the LoanSTAR program. An audit firm is assigned to each building based on expertise, geographical location and workload. The audit teams conduct the audit and prepare an engineering report detailing the energy conservation measures recommended. Task 1 personnel then conduct an independent review of all energy audit reports submitted by the consulting engineering firms. Reports are reviewed for use of appropriate technology, conceptual correctness, adequacy of implementation cost data, numerical accuracy, and compliance with program guidelines. The major functions of this task include: review of preliminary on-site screening reports, desktop audit reviews, conducting meetings with the engineering consulting firms, and the development of audit format training workshops.

Table 2 lists the approved retrofits to be implemented in the first year of the program. The estimated $4.2 million implementation costs will generate a $1.2 million annual savings, for an estimated 3.5 year simple payback. Roughly 40 buildings containing 5.1 million square feet of conditioned space will have been effected by various retrofits ranging from variable speed drives to lighting replacements.

2.3. Task 2: Selection and Installation of Monitoring Systems

This task ensures that adequate, reliable and affordable data are collected to monitor energy use of the buildings participating in the LoanSTAR program. Data collected

Figure 1: LoanSTAR Monitoring and Analysis Task Planning

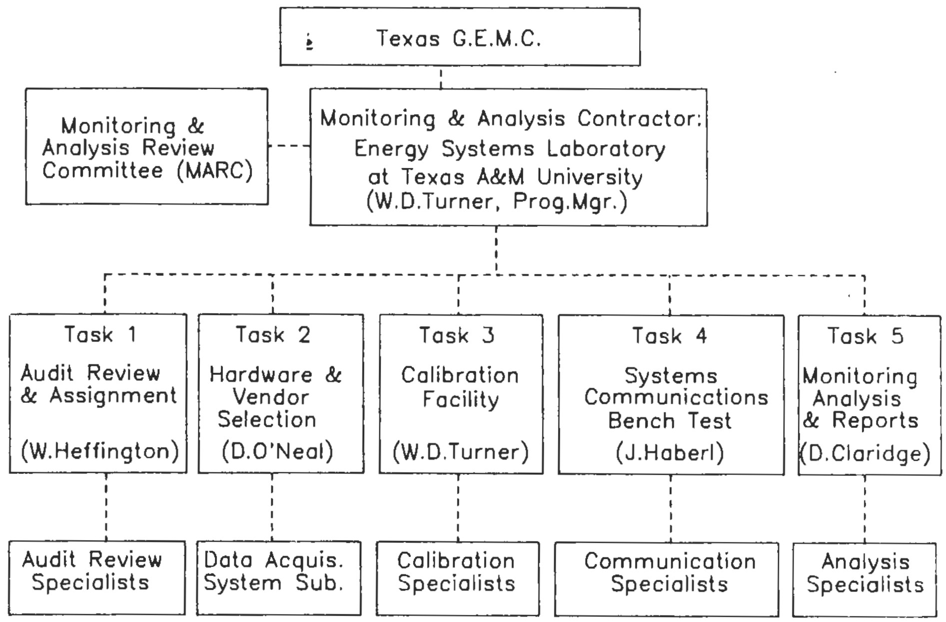

Table 2: Approved Retrofits for First Year Implementation

Category Type	# Buildings Effected	Conditioned Square Footage	Type of Retrofit
Office	12	2,610,745	Lighting, outside air mods, EMCS, Variable Freq. Drives (VFD), motion sensors, pump shutdown, rate schedule mods, 2-speed motor, hot water reset, HVAC mods, eddy current VSD, pump & motor mods.
Multipurpose	6	630,307	VAV, fan shutdown, timeclocks, motion sensors, lighting mods, Variable Frequency Drives.
Parking	3	607,247	Lighting, timeclocks, photocells
Library	3	362,723	Motion sensors, lighting mods, air handler mods, VFD, pump shutoff, night setback.
Classroom	4	344,663	Add chiller, expand EMCS, VFD, lighting mods, motion sensors, outside air mods.
Gymnasium	2	139,063	Lighting, VFD.
Laboratory	1	125,000	Heat recovery.
Dormitory	3	116,408	Motion sensors, lighting mods, VFD, thermostats, add chiller.
Phys. Plant	3	19, 636	Add chiller, DDC, EMCS, renovate pump system, steam shut-down, replace boiler.
Other	2	92,450	Outside air mods, VFD, replace rooftop unit w/ new chiller.
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TOTAL	40	5,064,040	

Total Estimated Savings = $1,209,221 (Combined payback 3.5 years)

Total Estimated Cost = $4,241,667

from the buildings will serve as the basis for determining the cost-effectiveness of different retrofits as well as providing indices of how well an individual building is performing. The major functions in this task include: data acquisition system subcontractor qualification and selection, determination of metering requirements at a given site, installation of metering systems, and metering system maintenance.

Four levels of metering systems have been developed for the energy monitoring program. These accommodate the necessary data requirements with the funds available for monitoring retrofits. The levels also are compatible with different hardware available on the market. As the project progresses, the definition of the levels and associated hardware requirements are expected to change. Table 3 contains guidelines for the energy monitoring levels.

Table four presents progress statistics from the first-year energy monitoring effort. About 410 channels of hourly information are being collected from 26 sites encompassing 2,750,000 square feet of conditioned space at an average cost per channel of about $1500. Thermal metering and large aggregations of electrical panels tend to dramatically increase the price per channel. Typical installation time is about 6 to 10 weeks from the approval of the loan and metering plan by the GEMC to the collection of the first hourly records.

Ongoing work at the DOE's National Laboratories and several universities shows that use of hourly data permits a more detailed analysis of end-use patterns and identification of major individual operating parameters within buildings than does the use of daily or monthly data [5, 6, 7, 2, 3, 8, 9].

Table 3: Guidelines for First Year Monitoring Costs

Monitoring Level	Retrofit Amount	Annual Energy Costs	Monitoring Costs
Level 0: (Utility data)	$20k - $50k	$10k - $30k	$0
Level 1: (1 - 4 channels)	$50k -$100k	$30k - $60k	$3k
Level 2: (4 - 20 channels)	$100k - $300k	$60k- -$200k	$10k
Level 3: (20+ channels)	$300k+	$500k+	$30k+

Table 4: First-Year Monitoring Estimates

Level	Number Channels (@ site)	Number of Buildings	Total Sq.ft.	ECRMS Being Monitored
1	1 to 6	14	1,750,000	VAV, lighting, Variable Speed Pumps, economizers, EMCS.
2	8 to 16	4	250,000	VAV, lighting, VSP.
3	30 to 50	8	750,000	VAV, boiler mods, chiller mods, VSP, EMCS.
TOTAL	410	26	2,750,000	

NOTE:

(1) The average cost per channel is about $1500. The thermal metering and large aggregation of electrical panels can raise the price per channel significantly.
(2) Typical installation time is about 6 to 10 weeks from the approval of the loan by the GEMC.

2.4. Task 3: Calibration Laboratory

The accuracy of the installed sensors is key to a successful energy monitoring project. Data obtained for this project must be accurate to maintain confidence and reliability. In order to assure that accurate data are collected, a National Institute of Standards and Technology (NIST) traceable calibration laboratory is being established at the Energy Systems Laboratory at Texas A&M University.

The objectives of the calibration laboratory are to: (1) construct a NIST-traceable facility which will be used to test sensors and verify their compatibility with selected energy monitoring systems; (2) establish a facility for troubleshooting faulty sensors found in the field; (3) construct a portable calibration system for in-situ field testing, troubleshooting, calibration, and validation; (4) have a facility to bench-test and pre-qualify proposed sensors and hardware prior to approval for installation in the field; and (5) develop improved calibration procedures for in-situ field testing.

This calibration facility will include the capability to measure dry-bulb, wet-bulb, and dew-point temperature, humidity, air and hydraulic pressure, air and liquid mass flow rates, air velocity, RPM, illumination levels, electrical energy, power factor, and solar radiation. Typically the calibration accuracy will be 2 to 10 times more accurate than the sensors being tested (as recommended by national calibration standards).

2.5. Task 4: Testing of Systems Communications

The purpose of this task is to conduct bench-mark communications testing of all field Data Acquisition Systems (DASs) for the LoanSTAR MAP. This includes testing the compatibility of sensors, DAS and the host computer. Public domain software, using open communications protocol, will be developed for polling, translating and analyzing the field data. Data acquisition systems that adequately satisfy the testing will then be approved for use in the program. The primary functions of this task include: the communications bench-test, and the software design, development, and testing.

In order to facilitate communications with any given manufacturer's field data recorder, the LoanSTAR program is developing a public domain Data Recorder Management System (DRMS). The DRMS will perform several functions, including: (1) remote programming of DASs, (2) scheduling the polling calls, and (3) translating the commands for and data records from any given manufacturer's DAS.

2.6. Task 5: Monitoring Plans, Analysis and Reports

This task analyzes collected data in order to determine the energy and dollar savings of the retrofits and reduce energy costs by identifying operational and maintenance improvements. This task also includes development of improved analysis methods, preparation of the overall project monitoring plan, the development of a LoanSTAR MAP computer network to conduct the analysis, the verification of audit assumptions through the analysis of energy use and site data, and the interaction and feedback to agencies and operators through ongoing analysis of the data.

2.7. Analysis Approach

The engineering savings estimates for the LoanSTAR retrofit measures rely on numerous assumptions made by the auditors. Most audits rely on estimates of electrical gains, building schedules, and lighting schedules. Reliable data obtained from monitored retrofits can be used to verify audit assumptions. In some cases this may lead to recalculated savings estimates. A procedure is being developed for "calibrating" the inputs used by the DOE-2 building simulation program. Since this program is large and time-consuming to use, it is being restricted to certain large installations. Similar "calibration" procedures for less detailed programs, such as ASEAM [10], are also being investigated.

The primary objectives which will influence the analysis methods used are the need to determine: (1) the overall cost savings due to the retrofits and (2) the savings and effectiveness of individual retrofits. These objectives lead to a requirement for different levels of analysis methods and tools.

Determination of overall cost savings implies a need for a standard evaluation technique which can be applied to all buildings. Since data from many buildings will be limited, a method which requires only whole-building data and weather data, such as PRISM [11] will be used as the standard evaluation technique. More detailed approaches will be explored when the available data warrants or as required to adequately determine overall savings.

The savings due to individual retrofits can vary from simple on-off tests to other cases which require the use of more sophisticated analysis techniques that incorporate a more inclusive set of influencing parameters and building characteristics. Models which incorporate simplified scheduling, extensive weather data and techniques such as principal component analysis [12] or single-valued decomposition [13, 7] are being investigated for these applications.

2.8. Measuring the Retrofit Savings

There are many ways of designing a procedure to measure the energy savings from energy conservation retrofits [14, 15]. Because of the diversity of the types of retrofits being monitored in the LoanSTAR program, each building will have its own metering and analysis plan. The plans can be categorized according to whether they are on-of, before-after, simulated occupancy, or test-reference. In general, the energy monitoring will rely either on the measurement of energy consumed directly at the device (sub-metered) or at the whole-building level. The types of data, variables to be measured, and frequency of measurement will be determined for each site. The primary types of data to be collected include point-in-time information and time-sequenced information, each of which can be obtained from data-base information or measured at the site.

2.9. Use of a Before-After Procedure to Measure Savings

Many of the retrofits in the LoanSTAR program will use before-after measurements to evaluate their effectiveness. Figure 2 shows a flowchart of the information required by a before-after experiment used to compare measured energy savings from a retrofit to audit estimates. Point-in-time and time-sequenced information, measurements of influencing parameters, and evaluations of system requirements all are necessary to determine before-after differences in the energy consumed, products delivered (e.g., comfort levels and illumination levels), and influencing variables. Before-after consumption, normalized for environmental, operational and system parameters in then compared to audit estimates to determine if the retrofit is operating as intended.

If there is a disagreement between measured and audit estimates, corrective action can be taken immediately to assure that the retrofit functions properly so as not to affect the projected payback. Periodically, feedback reports will be provided to building operators and agency managers to determine possible O&M savings opportunities. Over time, the data collected will serve to improve audit estimates by providing measured energy savings for various classes of energy conservation retrofits, and will provide a valuable data base for energy decision makers.

3. SUMMARY

This paper presents an overview of the Texas LoanSTAR program by outlining the program structure, energy monitoring efforts, equipment installation and calibration procedures, and analysis techniques. Throughout this paper publications are referenced that provide additional information on the design and implementation of large scale monitoring programs. Detailed reports concerning the LoanSTAR program, availability of metered data, and software developed can be obtained from the Energy Systems Lab at Texas A&M University.

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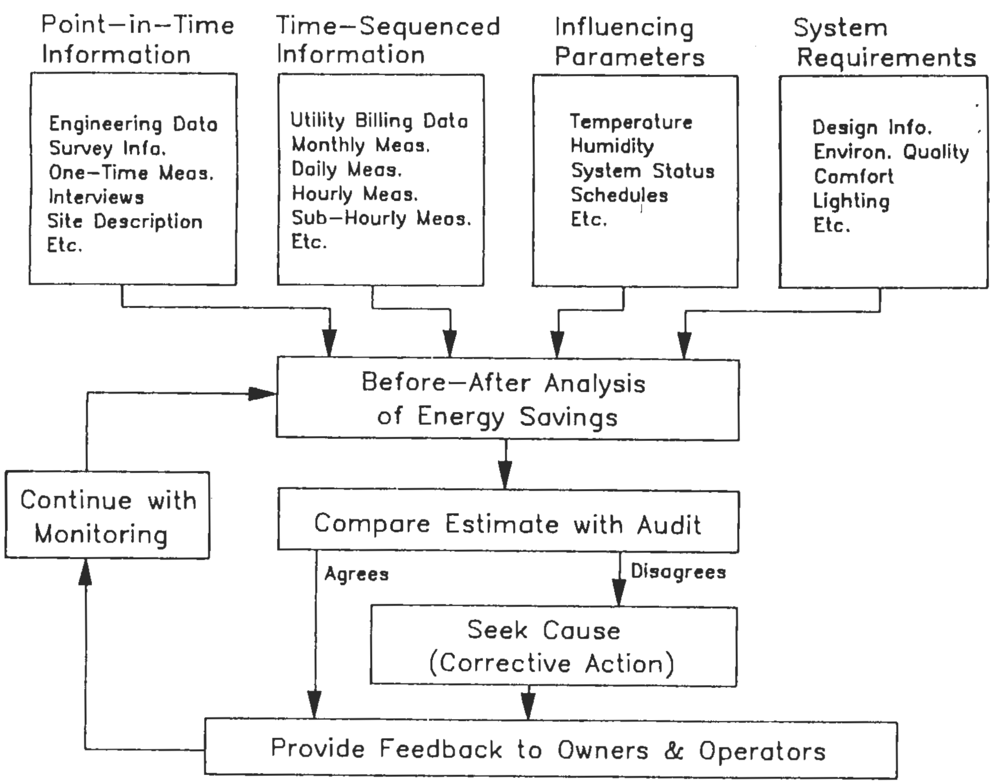
Figure 2: Before-After Analysis of Energy Conservation Retrofit Savings



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